Application Report
SNLA224–June 2014

Sending Power Over Coax in DS90UB913A Designs

ABSTRACT

The DS90UB913A was designed as a serializer to support automotive camera designs. Automotive cameras are often located in remote positions such as bumpers or trunk lids, and a major component of the system cost is the wiring. For this reason it is desirable to minimize the wiring to the camera. FPD III systems allow the video data, along with a bidirectional control channel, and power to all be sent over a single coaxial cable. This application report discusses the constraints involved in the power design portion of these applications.

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1 Overview of the Operation of the DS90UB913A

1.1 Forward Channel

The data that the DS90UB913A receives from the imager is encoded and serialized. The encoded word (payload) is 14 bits long, so for each PCLK, there are 14 bit cells output from the DS90UB913A. This means that with a 100 MHz PCLK, the serial rate out of the serializer is 1.4 Gbps, which corresponds to a bandwidth requirement of 700 MHz, or a unit interval time of 714ps.

1.2 Back Channel

The back channel is separated from the forward channel in the frequency domain. The back channel frequency is fixed and is nominally around 2.5 MHz, but it can change with process variation, power supply and temperature. The back channel frequency is kept low to minimize any potential interference with the forward channel.

2 Theory of Operation for Power Over Coax (POC)

Both the forward and the back channel are band limited. In the case of the backchannel, the band of interest is from 1 MHz up to about 4 MHz, and for the forward channel, we are interested in frequencies from about 70 MHz to 700 MHz. If the forward channel were operating at a lower PCLK rate, then the forward channel frequency band of interest would be scaled down to a lower band. For POC we want to design a circuit which will split the input signal into two branchs with one branch carrying the DC power for the POC circuit, and the second branch carrying the signals without the DC power. To do this, we put an element in the signal path branch which will pass both the backchannel and the forward channel, but block the DC. A simple capacitor will work for this – since a 0.1 uF capacitor has very low impedance from the start of the 1 MHz backchannel band through the 700 MHz upper limit of the forward channel band. . Parasitic inductance for a 0.1 uF 0603 capacitor is on the order if 1 nH, so it does not really come into play within the band of interest.

The second circuit – one which passes the DC, but doesn't interfere with the AC signal is a bit harder.

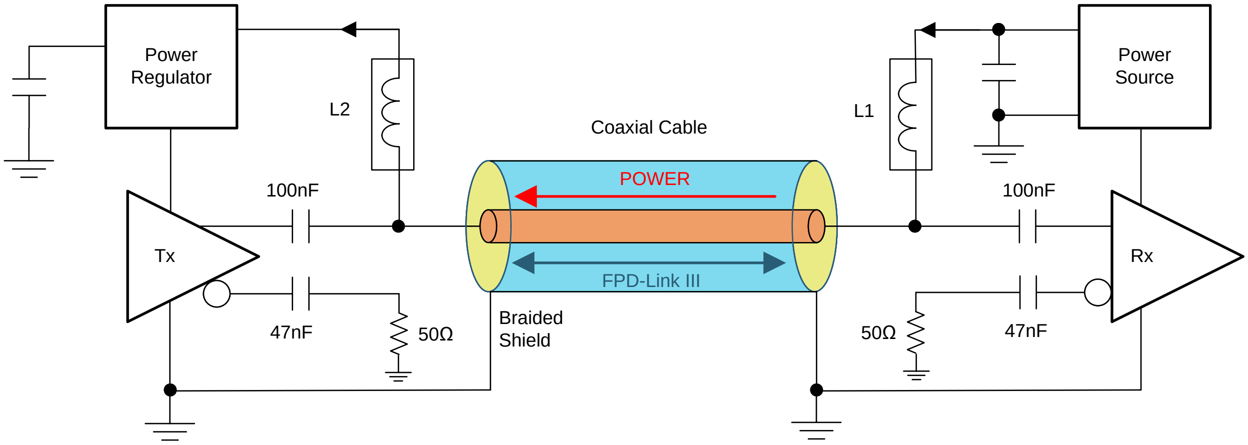

Figure 1. Concept for Power Over Coax

Since the data channels are being passed over a controlled impedance transmission line, we want to make certain that the impedance of the low pass circuit is large over the band of the forward channel . If we want the power circuit to not interfere with the datapath, then we want to make sure that the impedance of this circuit is > ~20X our characteristic impedance, so for a 50 Ω coax line, we want the impedance to be greater than 1 KΩ from 1 MHz up to 700 MHz Just like the capacitor worked for the datachannel, and ideal inductor would work for this application. Unfortunately, ideal inductors are much harder to find than ideal capacitors. To have >1 KΩ impedance at the 1 MHz lower band of the backchannel, we would need about a 100 µH inductor, but a typical 100 µH inductor has a parasitic capacitance which drops its impedance below 1 KΩ at frequencies above 70 MHz, so it would interfere with the forward channel.

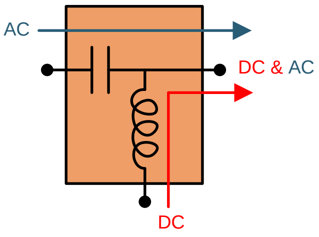

Figure 2. Separating the Power from the Signal Path with Inductor and Capacitor

3 A Real World Inductor

A good model for an inductor is to consider an ideal inductor, which has in parallel with it a series RC circuit. At low frequencies, the capacitor represents a very high impedance, and the inductor behaves as an ideal inductor. At very high frequencies, the capacitor looks like a short circuit, at which point the impedance is equal to R

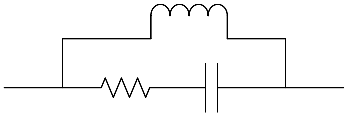

Figure 3. Model for a Real World Inductor

At a frequency of 1/√(LC) the inductor and capacitor resonate, and the impedance becomes very large. The net result is that if you measure the impedance of a real world inductor, you will get a curve with a shape such as that seen in Figure 4 where the blue line shows the impedance of an ideal inductor, the red line in Figure 4 shows the impedance of the parasitic capacitance, and the purple line shows the total impedance – this graph ignores the effect of the self resonance, which actually causes the real curve to peak more at the top, being more pointy rather than rounded off.

Besides parasitics and self resonance, there is another intrusion of the real world on inductors. Capacitors work by converting the electrical energy in the circuit into an electric field which is contained within the capacitor. The voltage across the cap is linearly related to the field strength up until the point when the dielectric breaks down, and then the capacitor ceases to behave as a capacitor – this voltage is known as the breakdown voltage, and every capacitor that you buy has a rated breakdown voltage – so long as this voltage is higher than the voltage at which the cap will be operating, the capacitor will behave as you would expect from a capacitor. Inductors operate in a similar fashion, except rather than storing energy in the form of an electric field, they store energy as a magnetic field within the core of the inductor. Just like a capacitor has a maximum voltage that it can support, an inductor has a maximum magnetic field strength that it can support, which is related to the current flowing through the inductor. As long as the current is below that limit, the inductor behaves like an inductor, but if you exceed the maximum current (known as the saturation current) then your inductor ceases to behave like an inductor.

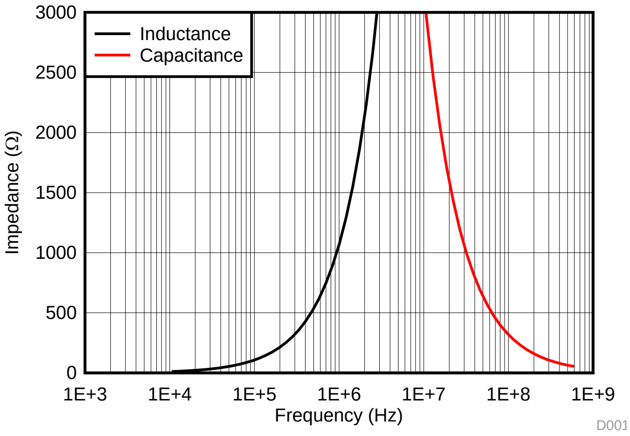

Figure 4. Real Inductor Impedance - 100 µH Inductor to Block Backchannel

4 Designing the Power Feed Circuit with Real Components

The circuit required must have very low impedance at DC, and the impedance must be >1 KΩ in both the backchannel band (1-4 MHz), and the forward channel band (PCLK*0.7 to PCLK*7) Ideally, the impedance is also above 1 KΩ in the region between the backchannel band and the forward channel band, but this is not strictly required.

A 100 µH inductor will have an impedance of 1 KΩ at 1 MHz, so this will cover the backchannel, and if the parasitic capacitance doesn't come into play at frequencies below 700 MHz, then this is all we need. Typically the shape of the impedance curve is symmetrical about the self resonance frequency on a log scale, so if we select a 100 µH inductor like the MSS7341T-104MLB from coilcraft, and look at the datasheet we will find that the Self Resonant Frequency (SRF) is 7.2 MHz, which means that the impedance will stay above 1 KΩ until about 50 MHz . Unfortunately 50 MHz is well below the forward channel band. Checking the saturation current of the MSS7341T-104MLB we see that it is about 0.5 A, so we need to make certain that our serializer design does not draw more than this amount of current, and if it does, then we need to find another inductor.

To boost the impedance of the circuit in the frequency band of the forward channel, we will need a second inductor. The lower edge of the forward channel band is 70 MHz at the maximum PCLK frequency, but if we want to allow for lower PCLK frequencies, we may want to select a lower frequency band – perhaps 35 MHz . To get 1 KΩ of impedance from an inductor at 35 MHz we need a value of 4.5 uH, so selecting the closest standard value gives us 4.7 uH. The Coilcraft pn 1008PS-472KLB is a 4.7 µH inductor, with a saturation current of 1.3 A, and a SRF of 160 MHz – this SRF means that the 4.7 uH inductor should be good up to greater than 700 MHz. This can be seen in Figure 3 where you can see the individual impedances of the 100 µH and 4.7 µH inductors, along with the composite of the two in series with the series combination, the impedance is very low at low frequencies, allowing the DC power to pass easily through the circuit, but from 1 MHz to over 1 GHz, the impedance is greater than 1 KΩ preventing interference with either the forward or the back channel. To keep the impedance from spiking too high, 1 KΩ resistors can be placed in parallel with each inductor, allowing the total impedance of that portion of the circuit to vary between 0 for DC and 1 KΩ for high frequencies.

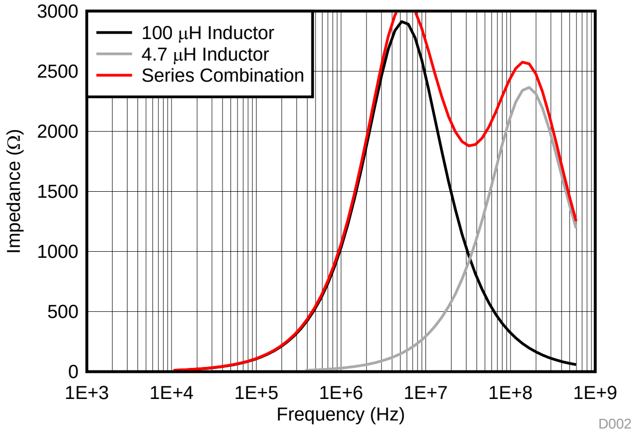

Figure 5. Impedance of Circuit Using Two Series Inductors

5 How to Use Smaller Inductors

The physics of the requirements dictate the values of the inductors that we use (100 µH and 4.7 µH), but the physical size is dominated by the ability of the core to sustain the magnetic field. Physically smaller inductors have lower saturation currents. One way to use a lower saturation current inductor is to reduce the current requirement of the circuit which can be done by increasing the voltage that is being carried by the coax cable. If our camera requires 1.5 W, and we are sending the power over the coax at a voltage of 5 V, then we will need 300 mA – and the 100 uH inductor that we selected is probably about the smallest physical size that we could tolerate (it is 7mm x 7mm x 4mm in size). However, if we went to a 12 V supply, then only 125 mA is required. The coilcraft 1812LZ-104 has a SRF of 12 MHz, a saturation current of 150 mA, and a footprint which takes up ¼ the space of the other inductor.

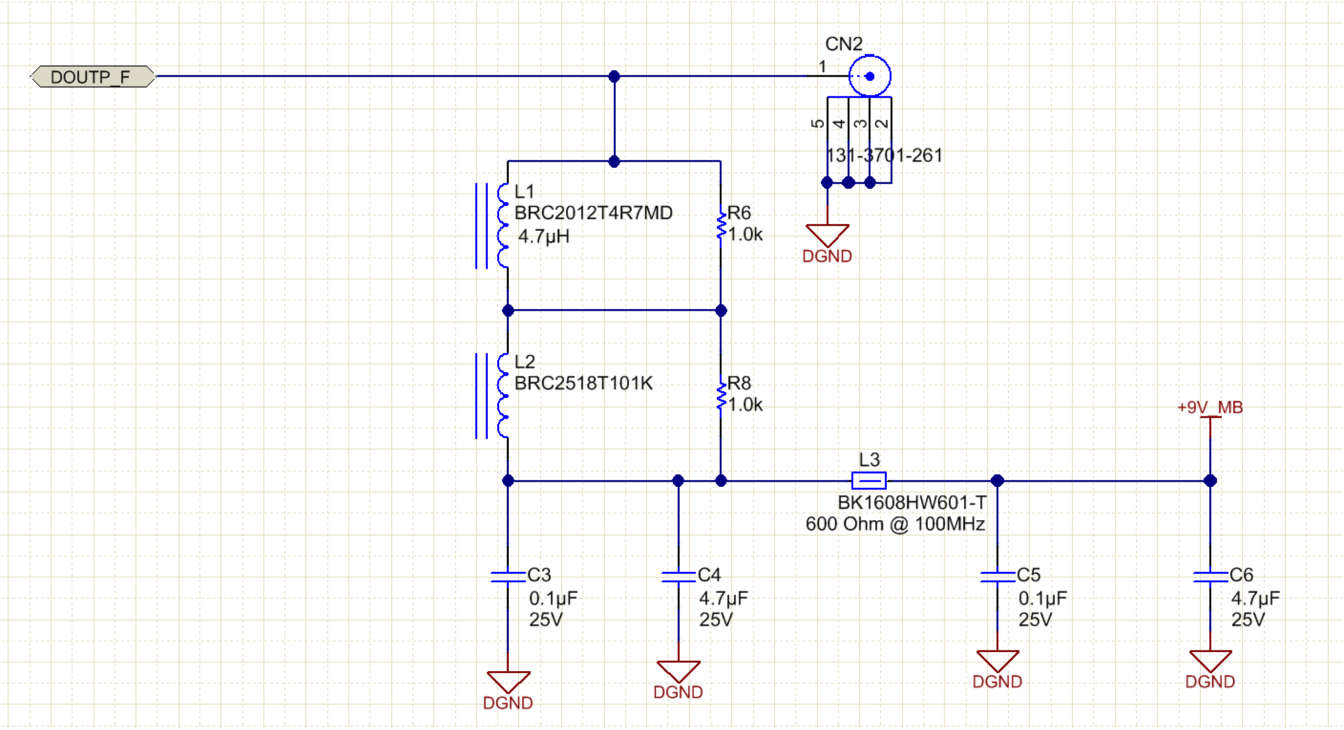

Figure 6. Example Camera Design with POC

6 Voltage Regulators

Once the voltage is transferred across the coax cable to the camera, there will be a need for various different power supply voltages. The LMR22007 simple switcher nano regulator is often a good choice for voltage regulator with it’s combination of programmable output voltage, very high efficiency (>90%) and physically small (1.6mm x 1.6mm) package. For lower voltages with minimal current, a miniature LDO such as the LP3990 is a good option

7 Summary

Power sufficient to power a small camera can be sent over the same coax cable that is being used for data transmission so long as the design makes certain that both the backchannel and forward channel bands are not interfered with. Most often this means a circuit with two series inductors – one which is ~100 µH for the back channel and one which is ~4.7 µH for the forward channel. The physical size of the inductors is dictated by core saturation, so if smaller size components are required, the voltage being sent over the cable must be increased, to decrease the current. Buck switching regulators can be used to provide regulated voltage supplies to the image sensor and serializer with very little loss of power.

Revision History

Version	Date	Notes
*	June 2014	First Release

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